AD-A286 032

ARMY RESEARCH LABORATORY

Statistical Analysis of Turbine Engine Diagnostic (TED) Field Test Data

Malcolm S. Taylor
U.S. ARMY RESEARCH LABORATORY

John T. Monyak
UNIVERSITY OF DELAWARE

ARL-TR-614

November 1994

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

NOTICES

Destroy this report when it is no longer needed. DO NOT return it to the originator.

Additional copies of this report may be obtained from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The use of trade names or manufacturers' names in this report does not constitute indorsement of any commercial product.

REPORT DOCUMENTATION PAGE			Form Approved OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1994	Final, August 1993–June 1994

4. TITLE AND SUBTITLE

Statistical Analysis of Turbine Engine Diagnostic (TED) Field Test Data

5. FUNDING NUMBERS

4B026-401-35

6. AUTHOR(S)

Malcolm S. Taylor and John T. Monyak*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
ATTN: AMSRL-CI-S
Aberdeen Proving Ground, MD 21005-5067

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
ATTN: AMSRL-OP-AP-L
Aberdeen Proving Ground, MD 21005-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TR-614

11. SUPPLEMENTARY NOTES

* Mr. Monyak is a graduate student from the University of Delaware.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

During the summer of 1993, a field test of turbine engine diagnostic (TED) software, developed jointly by the U.S. Army Research Laboratory and the U.S. Army Ordnance Center and School, was conducted at Fort Stuart, GA. The data were collected in conformance with a cross-over design, some of whose considerations are detailed. The initial analysis of the field test data was exploratory, followed by a more formal investigation. Technical aspects of the data analysis and insights that were elicited are reported.

14. SUBJECT TERMS

statistics, software development, field test, experimental design, data analysis

15. NUMBER OF PAGES

19

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

INTENTIONALLY LEFT BLANK.

PREFACE

This report was to have been coauthored with Dr. Henry B. Tingey, Professor of Mathematical Sciences, University of Delaware. Dr. Tingey contributed significantly to the design of the experiment and endured record-breaking temperatures in the field to be present during data collection. His untimely death less than 6 mo later prevented him from seeing this project to its conclusion.

The data had been entrusted to John Monyak, a graduate student in the Department of Mathematical Sciences at the University of Delaware, for computational interrogation. Mr. Monyak wanted to complete the analysis of the data, and so a course of action was decided upon. At the end, it was clear that Mr. Monyak's contribution would not be adequately reflected through an acknowledgment and so he appears as coauthor.

INTENTIONALLY LEFT BLANK.

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK.

LIST OF TABLES

INTENTIONALLY LEFT BLANK.

1. INTRODUCTION

During the week of 15–21 August 1993, a field test of turbine engine diagnostic (TED) software was conducted at Fort Stuart, GA.

The participants in the test were personnel from Support Squadron, 278th Armored Cavalry Regiment (ACR) and 771st Maintenance Company, 176th Maintenance Battalion, of the Tennessee National Guard (TNNG). The TNNG had at that time only begun transition to the M1 Abrams main battle tank (MBT) and hence brought negligible prior experience repairing the engine to the field test. Some of the participants had never before seen the AGT-1500 turbine engine. Thirty soldiers took part in the exercise. They were chosen so that three levels of skill were equally represented. Three groups of 10 soldiers—10 having ranks E1–E4, 10 with rank E5, and 10 with ranks E6–E7—represented the different skill levels.

1.1 Test Configuration. Four AGT-1500 engines, removed from the MBT to duplicate the environment in which the mechanic will be working, were used. The engines were physically located to ensure the integrity of the data collected (i.e., they were sufficiently isolated to obviate verbal and/or visual communication between sites). At two of the engines, TED software loaded on an IBM-compatible 486 DX color notebook computer was provided, and at the remaining two engines the paper technical manual (TM) currently fielded was available for use by the participants.

On each of the four engines, several faults† that would normally require attention by a mechanic were installed. The number of faults installed on a specific engine ranged between two and four inclusively and was randomly determined prior to the start of the test. The particular faults that were installed were again chosen at random from a list of possible problems determined by a master mechanic to be comparable in difficulty of detection. In this way, each engine was rendered unique in that the number of faults and the nature of faults presented to the mechanic differed between engines. The entire process of fault assignment was repeated for each engine at the beginning of each day of testing to avoid any carryover of information from the previous day.

† The term "fault" is taken here to mean a condition that requires mechanical intervention (i.e., replacement of a part, adjustment of an existing part, or further diagnostic inquiry).

1.2 Test Conduction. Since some constraints on scheduling the soldiers' arrival at the test site had to be observed, the order in which an individual entered the test was not completely arbitrary. However, within each level of proficiency, the troops were randomly assigned to one of two experimental regimens. Half used TED followed by the TM while the other half used the TM followed by TED, and once an individual commenced on test, both methods were used, one following the other. Each soldier was randomly assigned to an engine with TED software and to an engine with the TM. This was equivalent to assigning faults to be identified.

The random assignment of number and type of faults to engine, troops to engine, and troops to experimental regimen, is necessary to disrupt systematic errors (anticipated or unseen) that might infiltrate the data collection and analysis and distort the results. The symmetry of group makeup—3 groups of 10, half using TED first and half using the TM first—maintains balance in the data and facilitates its subsequent analysis. The data are being collected in accordance with a statistical experimental design called a cross-over design.

1.3 Data Collection. The mechanics were instructed to conduct a complete visual inspection of the engine and to complete DA Form 2404, Equipment Inspection and Maintenance Worksheet. The TED software directs both the order of inspection and the items inspected. The TM does not structure the inspection process. The test phase using TED and the TM terminated when visual inspection was complete or when 60 min elapsed. The maximum time on test for a participant was thus limited to 120 min.

For each subject, and for each device (TED vs. the TM), a time history of fault detection was recorded:

TM: Start_______(fault, time)_______(fault, time)_______ _ _ _ End (Complete/60 min)
TED: Start_______(fault, time)_______(fault, time)_______ _ _ _ End (Complete/60 min).

These data were recorded by an observer stationed at each engine. The observer's task was to collect data without interacting with or coaching the mechanic on test. Although TED has the facility to record a time history automatically, most observers continued to record data manually and include anecdotal remarks which, although not part of the data analysis, were still of qualitative value. Data collected in this format

will support determination of the myriad descriptive statistics which may be of interest as well as facilitating more specialized statistical analyses.

2. TECHNICAL DISCUSSION

2.1 Summary Statistics. The initial analysis of the data from the field test was one of an exploratory nature. Sample means and standard errors were computed for all relevant variables in the analysis. The measure of performance was the percent of faults detected. Also measured was the total amount of time spent by the technician in the repair effort.

Most importantly, we see a mean percent correct of 51% for the TED software and 26% for the TM in Table 1. We also see a similar increase in percent detection at each skill level as indicated in Tables 2–4. At the highest level, which consists of soldiers with ranks of E6–E7 (denoted skill level 1), we see an increase from 42% correct for the TM to 58% correct for TED. At the medium skill level (E5, skill level 2), we see an improvement in percent detected from only 11% for the TM to 42% for TED. Finally, at the lowest skill (E1–E4, skill level 3), we see an increase from 26% to 52%.

It is noteworthy that in the field test, the lowest skill level (E1–E4) actually outperformed the medium skill level (E5). The skill level 3 technicians averaged a 39% correct score over both methods compared to an average 26% correct for skill level 2. The highest skill level (E6–E7) averaged 50% correct.

From the summary statistics, we also see a much higher mean length of time spent on repair with TED than with the TM. The mean time spent on repair for each device is shown in Table 5. The average time spent by a technician on repair with TED was 49 min compared with an average of only 20 min with the TM. This longer time length may help explain the superiority (in terms of detection ability) of TED over the TM. TED seems to encourage the technicians to spend more time on solving the problem (perhaps because it is less frustrating than the TM).

Also from the summary statistics, we see that the observed difficulty of the faults does not appear to be the same. Certain faults seemed easier to detect than others. The easiest appeared to be faults No. 2 and No. 11, which were detected about three-fourths of the time. The most difficult faults appeared to

Table 1. Summary of Assigned Faults Detected—All Skill Levels Combined

Device	No. Assigned	No. Detected	Percent Correct
TM	97	25	26
TED	97	49	51

Table 2. Summary of Assigned Faults Detected—Skill Level 1

Device	No. Assigned	No. Detected	Percent Correct
TM	31	13	42
TED	33	19	58

Table 3. Summary of Assigned Faults Detected—Skill Level 2

Device	No. Assigned	No. Detected	Percent Correct
TM	35	4	11
TED	33	14	42

Table 4. Summary of Assigned Faults Detected—Skill Level 3

Device	No. Assigned	No. Detected	Percent Correct
TM	31	8	26
TED	31	16	52

Table 5. Mean Time Spent on Repair

Device	Time for Repair (min)
TED	49.33
TM	19.89

be No. 13† and No. 15,†† which were never detected. The complete table of means for the faults is shown in Table 6. A list of fault codes is included in the appendix.

Table 6. Percent Correct for Each Fault

Fault No.	No. of Observations	Percent Correct
2	8	75
3	15	40
4	8	50
5	8	63
6	22	23
8	7	43
9	14	57
11	15	73
13	15	0
14	8	50
15	8	0
16	7	57
17	8	63
19	8	63
21	7	14
24	7	14
25	14	8
28	8	13
29	7	57

† Fault No. 13 (loose nut on PTS cable mounting bracket) required the mechanic to assume an awkward position to detect.

†† Fault No. 15 (fuel in the underside of the PTS actuator) was compromised when the fuel evaporated.

The mean rates of detection for each of the installed faults is further broken down by device used in Table 7. Here we see that the improvement in fault detection with TED over the TM varies from fault to fault. TED appears to have great improvement over the TM on faults No. 5, No. 6, No. 17, and No. 19. The TM appears to outperform TED for some faults, especially No. 14. It turns out that these faults are the ones whose differences in percent correct (TED vs. the TM) are statistically significant.

Finally, Table 8 shows the mean percent correct for each device type by order position. By order position, we mean whether the repair effort was the first of the day for the technician or the second. In general, we see that the mean percent correct for the second test is slightly lower than for the first test. This may be due to a "fatigue" effect. That is, the second engine repaired may have had a lower percent correct because of fatigue on the part of the technician. However, this overall decrease is not statistically significant.

Initially, there was a concern that a "learning effect" would occur. That is, it was suspected that technicians who had used TED first would get a higher percent detected with the TM than those technicians who had used the TM first because they would have learned something from having used TED first. From Table 8, we see that the mean percent correct for the TM actually dropped slightly from 28% correct to 24% correct when it was preceded by using TED. Whether preceding TED or not, it appears that the two devices differ by about 25 percentage points. Thus, from the table of means, it appears that no "learning effect" has occurred. Surprisingly, we see later that there is, in fact, evidence of a learning effect when we adjust for the effect of another variable, the difficulty of fault detection. The implication for is discussed later in the report.

2.2 <u>Probabilistic Models</u>. Because the data were generated from a cross-over design, the usual factors to consider would be the device effect (TED vs. the TM), the skill level, and the order position of the test. Also one might wish to block on subjects (technicians) or days to remove extra variability. Initial analyses, however, showed these blocking factors to be nonsignificant, and they were dropped from future models.

The DEVICE, SKILL, and ORDPOS (order position) factors were included in a model using the proportion correct as the response. A linear weighted least-squares model and a logistic model were both fit, giving essentially similar results. The analysis of variance (ANOVA) table for the logistic regression is shown in Table 9.

Table 7. Percent Correct by Device Type for Each Fault

Fault No.	Device	No. of Observations	Percent Correct
2	TM TED	4 4	50 100
3	TM TED	4 11	50 36
4	TM TED	4 4	25 75
5	TM TED	4 4	25 100
6	TM TED	11 11	0 45
8	TM TED	7 0	43 —
9	TM TED	7 7	43 71
11	TM TED	4 11	50 82
13	TM TED	11 4	0 0
14	TM TED	4 4	100 0
15	TM TED	4 4	0 0
16	TM TED	0 7	— 57
17	TM TED	4 4	25 100
19	TM TED	4 4	25 100
21	TM TED	7 0	14 —
24	TM TED	0 7	— 14
25	TM TED	7 7	0 14
28	TM TED	4 4	0 25
29	TM TED	7 0	57 —

Table 8. Percent Correct by Device Type for Each Order Position

Order Position	Device	Percent Correct
First	TM TED	28 53
Second	TM TED	24 48

Table 9. ANOVA Table for Initial Model

Source	DF	Chi-Square	P-Value
Intercept	1	11.39	0.0007
SKILL	2	8.49	0.0143
DEVICE	1	12.24	0.0005
ORDPOS	1	0.15	0.6956
SKILL*DEVICE	2	2.05	0.3593
SKILL*ORDPOS	2	1.79	0.4080
DEVICE*ORDPOS	1	0.05	0.8305
LIKELHD RATIO	2	3.20	0.2015

We see a significant effect for device used and skill level. That is, the use of TED or the TM made a significant impact on the proportion correct as did the skill level of the technician. The effect of order position was not significant. Interaction effects in this model, including the DEVICE*ORDPOS interaction, were also not significant. This means that, for this model, the effect of device does not depend on the level of order position, and, hence, there appears to be no learning effect. Note, however, that the effect of difficulty of fault detection has not yet been incorporated into the model.

One of the assumptions of the field test was that the difficulty of detection of each of the faults was constant. That is, no fault was easier to detect than any other. However, this assumption is not supported by the data. Models with the assigned fault as a variable (called AFLT) showed a significant effect on

the proportion correct from this variable. This implies that the mean detection rate for each fault is not the same.

In order to deal with this assumption violation, another model which included the AFLT as a factor was fit. The ANOVA table for this model is shown in Table 10. The idea was to determine if the device effect was still significant when the effect of fault difficulty was removed from the model. Again, a linear weighted least-squares model on the proportion correct along with a logistic model was fit. The results were again similar with the two models. Since the cell frequencies are relatively small for this model (there are 19 AFLT levels), the linear weighted least-squares ANOVA table is shown.

Table 10. ANOVA Table for Adjusted Model

Source	DF	Partial-F	P-Value
SKILL	2	19.03	0.0001
DEVICE	1	10.72	0.0014
AFLT	18	3.86	0.0001
ORDPOS	1	0.63	0.4298
SKILL*DEVICE	2	4.47	0.0135
SKILL*ORDPOS	2	0.94	0.3926
DEVICE*AFLT	13	2.02	0.0248
DEVICE*ORDPOS	1	5.48	0.0210
ERROR	153		

We see, most importantly, that the device effect remains significant in this model. That is, even when accounting for the differential difficulties of the faults, TED still is superior to the TM. We see, as before, a significant effect from skill level. The effect of assigned fault is also evident.

However, we also see in this model a significant device by assigned fault interaction effect. This means that the effect of device on the proportion correct depends on the fault involved. That is, TED's improvement over the TM depended upon which fault was considered. We saw evidence of this effect in the summary statistics in Table 10. Specifically, it appears that TED does best over the TM for faults

in the summary statistics in Table 10. Specifically, it appears that TED does best over the TM for faults No. 5, No. 6, No. 17, and No. 19. Alternatively, the TM appears to perform best over TED for fault No. 14.

There is also a significant device by skill effect in the model. This indicates that the effect of the device depends upon the level of skill. As mentioned in section 1, it appears that technicians with a lower mean detection rate on the TM are most helped by TED while those with a higher mean detection rate for the TM are helped least. However, there does appear to be a benefit from TED over the TM even for the more highly skilled technicians.

Note that the DEVICE*SKILL effect was not significant in the initial model summarized in Table 9. The interpretation is then that the "extra" advantage of TED over the TM for lower skilled technicians was not seen in the first model because its effect was masked by the differential effects of fault difficulty.

From the adjusted model, we also see a significant device by order position (DEVICE*ORDPOS) interaction effect. This implies that the effect of device type depends on the order position. Specifically, for the first-order position, the model predicts a larger advantage of TED over the TM than for the second-order position. That is, TED's advantage over the TM was more pronounced during the first time period than during the second. But since technicians using the TM in the second time period had already had access to TED (in the first time period), this better performance of the TM may actually be the result of something the technicians learned from the TED the time period before. This is the suspected "learning effect" mentioned earlier. If this is truly the result of a learning effect, then the evidence for the superiority of TED over the TM is actually greater than it appears. However, since the advantages of TED over the TM is already overwhelming, the importance of any learning effect is small.

Again, this interaction effect was not significant in the earlier model because of its lack of adjustment for fault difficulty.

3. RESULTS SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Clearly, we see a benefit from the TED software over the currently used TM. This benefit cannot be attributed merely to differences in skill levels, difficulty of fault detection, or the order of tests. The benefit from TED software is strongly evident.

There is some indication that the benefits of TED over the TM may depend upon the fault in question. However, the sample sizes for each of the 19 faults used were quite small, and conclusions about the specific faults on which TED performs better or worse should be made with caution. Another experiment to study this specific question would be advised, especially since this experiment was not designed to answer that question.

There is clearly a benefit from TED for all skill levels although there is some evidence that lower skilled technicians may benefit more from TED than do higher skilled ones. Since none of the technicians had extensive experience on the M1 Abrams MBT, we cannot infer what the benefits of TED would be for technicians experienced on the M1.

The TED software appears to roughly double the chances of detecting a fault over the TM. This may be in part because technicians spend, on average, a longer amount of time on repair with TED than with the TM. The increased diagnostic time is far outweighed by the attendant superiority in fault identification.

In summary, there is very strong statistical evidence from the field test at Fort Stuart to support the use of TED software over the TM in the repair of the M1 Abrams MBT.

INTENTIONALLY LEFT BLANK.

APPENDIX:

LIST OF FAULT CODES

INTENTIONALLY LEFT BLANK.

LIST OF FAULT CODES

1. Loosen inside plenum seal clamp.
2. Remove nut(s) from one of the bolts retaining the foreign object damage (FOD) screen.
3. Remove the T1 sensor.
4. Disconnect inlet guide vane (IGV) return spring.
5. Loosen reduction gear box (RGB) air line clamps.
6. Put oil in hydraulic pump seal area to simulate a leaking seal.
7. Loosen line at fuel cutoff solenoid.
8. Remove pins from both IGV and power turbine stator (PTS) solenoid at the electromechanical fuel system (EMFS).
9. Remove a bolt from the fuel pump.
10. Loosen air bleed nut at the fuel inlet feed line.
11. Remove a bolt from the fuel nozzle and loosen two others.
12. Loosen nut on PTS cable (mount).
13. Loosen nut on PTS cable mounting bracket.
14. Disconnect PTS cable rubber boot.
15. Put fuel in the underside of the PTS actuator.
16. Put oil on the No. 5 and (or) No. 6 oil lines.
17. Remove several bolts (4–5) from exhaust duct.
18. Loosen or tighten (unadjust) the air bleed bolt.
19. Remove the air bleed spring.
20. Loosen engine/transmission mounting bolts.
21. Remove oil cooler lines mounting brackets.
22. Remove a few of the rear module drain lines.
23. Loosen oil lines on oil reservoir.
24. Remove oil reservoir mounting pin safety clip.
25. Put foreign particles on the chip collectors.
26. Loosen fuel quick disconnect (QD).
27. Put oil around the base of the oil filter.
28. Squirt fuel into the EMFS weep hole.
29. Remover cotter pin from strut assembly.

INTENTIONALLY LEFT BLANK.

NO. OF COPIES	ORGANIZATION
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN: DTIC-DDA CAMERON STATION ALEXANDRIA VA 22304-6145
1	COMMANDER US ARMY MATERIEL COMMAND ATTN: AMCAM 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN: AMSRL-OP-SD-TA/ RECORDS MANAGEMENT 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LABORATORY ATTN: AMSRL-OP-SD-TL/ TECHNICAL LIBRARY 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN: AMSRL-OP-SD-TP/ TECH PUBLISHING BRANCH 2800 POWDER MILL RD ADELPHI MD 20783-1145
2	COMMANDER US ARMY ARDEC ATTN: SMCAR-TDC PICATINNY ARSENAL NJ 07806-5000
1	DIRECTOR BENET LABORATORIES ATTN: SMCAR-CCB-TL WATERVLIET NY 12189-4050
1	DIRECTOR US ARMY ADVANCED SYSTEMS RESEARCH AND ANALYSIS OFFICE ATTN: AMSAT-R-NR/MS 219-1 AMES RESEARCH CENTER MOFFETT FIELD CA 94035-1000

NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY MISSILE COMMAND ATTN: AMSMI-RD-CS-R (DOC) REDSTONE ARSENAL AL 35898-5010
1	COMMANDER US ARMY TANK-AUTOMOTIVE COMMAND ATTN: AMSTA-JSK (ARMOR ENG BR) WARREN MI 48397-5000
1	DIRECTOR US ARMY TRADOC ANALYSIS COMMAND ATTN: ATRC-WSR WSMR NM 88002-5502
1	COMMANDANT US ARMY INFANTRY SCHOOL ATTN: ATSH-WCB-O FORT BENNING GA 31905-5000
	ABERDEEN PROVING GROUND
2	DIR, USAMSAA ATTN: AMXSY-D AMXSY-MP/H COHEN
1	CDR, USATECOM ATTN: AMSTE-TC
1	DIR, USAERDEC ATTN: SCBRD-RT
1	CDR, USACBDCOM ATTN: AMSCB-CII
1	DIR, USARL ATTN: AMSRL-SL-I
5	DIR, USARL ATTN: AMSRL-OP-AP-L

NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY TANK-AUTOMOTIVE COMMAND ATTN: SFAE-ASM-AR-LA WARREN MI 48397-5000
1	DIRECTOR NATIONAL GUARD BUREAU 111 S GEORGE MASON DR ARLINGTON VA 22204
1	COMMANDER US ARMY COMBINED ARMS SUPPORT COMMAND ATTN: ATCL-MEF FORT LEE VA 23801
1	DIRECTOR STRATEGIC LOGISTIC AGENCY ATTN: LOSA-SP 5001 EISENHOWER AVE ALEXANDRIA VA 22333
1	COMMANDER US ARMY ARMOR CENTER ATTN: ATZK-CDS/MAJ MALHAM FORT KNOX KY 40121
	ABERDEEN PROVING GROUND
26	DIR, USARL ATTN: AMSRL-CI-CA/ J DUMER T HANRATTY R HELFMAN SP5 W CUNNINGHAM LTC O ILLI AMSRL-CI/W MERMAGEN AMSRL-CI-S/ A MARK B BODT M TAYLOR (15 CP) AMSRL-WT-WE/J THOMAS AMSRL-WT-PB/D WEBB AMSRL-SL-BV/W BAKER

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. ARL Report Number **ARL-TR-614** ________ Date of Report **November 1994**

2. Date Report Received ________

3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) ________

4. Specifically, how is the report being used? (Information source, design data, procedure, source of ideas, etc.) ________

5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. ________

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) ________

CURRENT ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)
(DO NOT STAPLE)

DEPARTMENT OF THE ARMY

OFFICIAL BUSINESS

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 0001, APG, MD

Postage will be paid by addressee

Director
U.S. Army Research Laboratory
ATTN: AMSRL-OP-AP-L
Aberdeen Proving Ground, MD 21005-5066